DETERMINING FOREST SPECIES COMPOSITION USING HIGH SPECTRAL RESOLUTION REMOTE SENSING DATA

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The primary goal of this research project was to investigate the use of high spectral resolution remote sensing imagery for the identification of forest species composition. In previous work we have successfully used data from AVIRIS to identify the nitrogen and lignin concentration in forest canopy foliage (Martin 1994; Aber and Martin 1995). We have extended this research by using these AVIRIS canopy chemistry data products to identify forest species composition.

The study site for this project is the Prospect Hill tract at the Harvard Forest, in central Massachusetts (Latitude 42°32'N Longitude 72°11'W). This 400 hectare research site contains a combination of natural hardwood, mixed hardwood/conifer, hemlock, and white pine stands as well as red pine and Norway spruce plantations. Image data for this site were acquired using NASA's Airborne Visible Infrared Imaging Spectrometer (AVIRIS) on 15 June 1992. Atmospheric corrections of the AVIRIS data were done by the Atmosphere Removal Program (ATREM) (Gao *et al.* 1991, 1992).

In a 1986 stand survey, 252 stands within the study site were identified from aerial photos. Basal area by species was measured at variable radius plots within each stand. The relative basal area of each species was used to place each stand into one of 11 categories which we then classified using AVIRIS spectral data (Table 1). These categories include stands of pure conifer species (red pine, Norway spruce, white pine and hemlock). Within the study area there were few stands containing single hardwood species. For this reason, the classification for this site concentrates on conifer stands.

An investigation of leaf samples analyzed for nitrogen and lignin concentrations demonstrates that individually these constituents cannot be used to differentiate between species. However, species identification can be made on the basis of both foliar nitrogen *and* lignin information (Figure 1). For example, red pine and hemlock have similar nitrogen concentrations but very different lignin concentrations, whereas red maple and black cherry have similar lignin concentrations and different nitrogen concentrations.

Multiple linear regression analysis previously used to select AVIRIS bands correlated with field measured canopy chemistry provided a subset of AVIRIS bands for this study. Bands in both the visible and near infrared (NIR) regions of the spectra were used in this analysis. The species map generated from the AVIRIS classification (Figure 2), uses 4 bands centered at the following wavelengths: 627, 755, 822 and 1641nm. The 3 shorter wavelength bands are used in equations predicting foliar lignin concentration, and the band centered at 1641nm is used to predict foliar nitrogen concentration (Martin 1994; Aber and Martin 1995). A supervised classification (ERDAS 1992) was done in which 2-8 polygons from each of the 11 species categories were used to extract spectral signatures for each class. These polygons were identified using the stand map generated from field data. A maximum likelihood algorithm was used, with a first pass parallelepiped classification, to assign all pixels in the image into one of the 11 signature classes.

Samples were selected from the classified image to assess the accuracy of the classification algorithm. Samples were selected from the center of classified polygons and compared to the field survey data (3x3 pixels per sample). Approximately 13% of the classified map was used in this accuracy assessment, with the number of samples per class relative to the total area of the class. The overall accuracy of the classification is 73.4%, with 127 out of 174 samples correctly classified. The only 'pure' species stands that we attempted to separate were conifer stands of hemlock, Norway spruce, white pine, red pine and black spruce bog. In the random samples chosen for our accuracy assessment, these species were correctly classified by AVIRIS data in 100, 90, 50, 89 and 87% of the samples, respectively.

We also validated these predictions against a number of plots in which canopy biomass had been measured by litterfall collections. Litterfall collections were made on 33 plots within this study site duing 1992 and 1993. These plots matched only 4 of the 11 classes described in Table 1. The number of these plots correctly classified with AVIRIS data is as follows: hemlock: 1/1, Norway spruce: 3/3, hardwood: 19/24, and red pine: 4/5.

The overall appearance of the AVIRIS classified map shows more spatial heterogeneity than the field classified map. It is possible that small scale spatial variation which might be missed in this type of field survey could be measured by remote sensing data, where spectral data is available for every pixel. The field sampling involved three or more measurements within each stand polygon (with some stands containing several hundred 20x20m pixels). Subsequent field observations have shown that a number of stands classified as mixed hardwood/conifer actually contained clusters of conifer species within the primarily hardwood stand.

This work demonstrates that the same bands used to derive foliar chemistry from high spectral resolution data can be used to classify forest species. Remote sensing of canopy chemistry has been possible only in the recent past with the availability of data from such instruments as AVIRIS. Additional work must be done to fully explore the potential of high spectral resolution data in determining forest species composition. Selection of signature training sites based on field measured canopy composition, rather than basal area, may result in a more accurate classification, particularly in mixed hardwood/conifer stands. Improvements may also be made in the classification of hardwood/conifer mixed stands by first using leaf-on and leaf-off data to determine the foliar biomass proportion of this mix before attempting species classification.

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	Stand Type	Classification Criteria
1	open	no trees
2	hemlock/hardwood	$\geq$ 70% hemlock
3	softwood	$\geq$ 80% mixed softwood
4	Norway spruce	$\geq$ 80% norway spruce
5	white pine	$\geq$ 80% white pine
6	red pine	$\geq$ 80% red pine
7	spruce bog	black spruce wetland
8	hardwood bog	wetland with mixed hardwood
9	hardwood	$\geq$ 80% mixed hardwood
10	hardwood/conifer 1	26-79% hardwood
11	hardwood/conifer 2	$\leq$ 25% hardwood

Table 1: Stand classification criteria

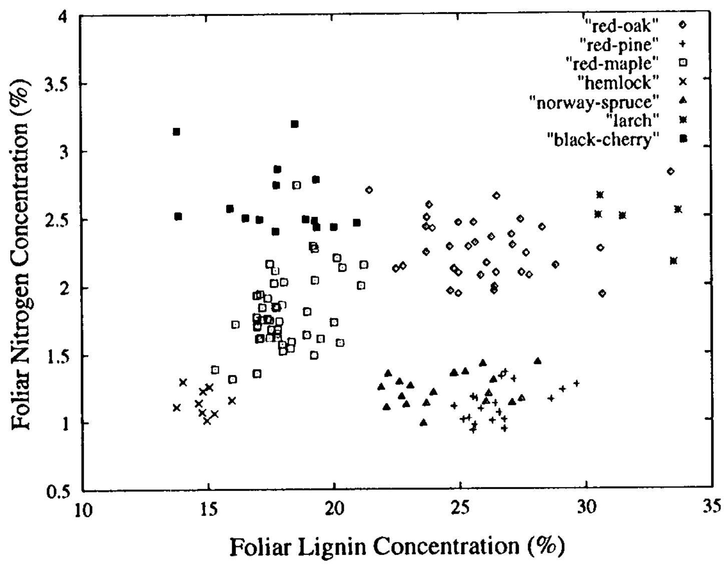

Figure 1: Harvard Forest leaf samples: foliar nitrogen vs foliar lignin

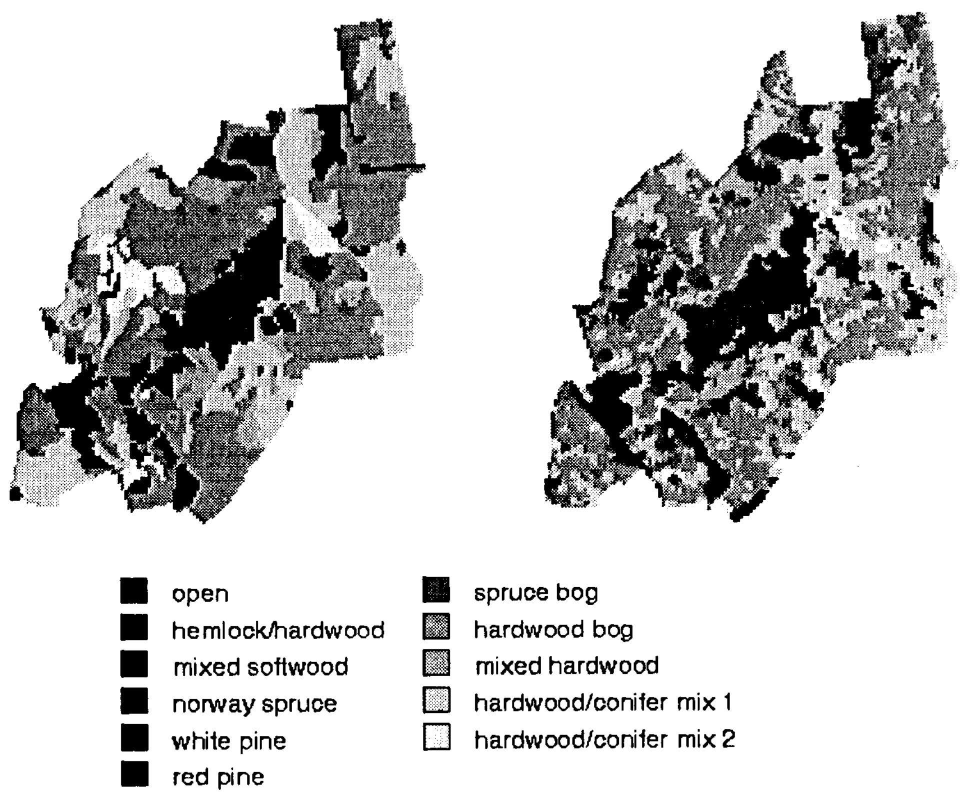

Figure 2: Harvard Forest: a. Species stand classification determined from field measurements of basal area. b. Species stand classification from AVIRIS data using bands centered at 627, 755, 822 and 1641nm.